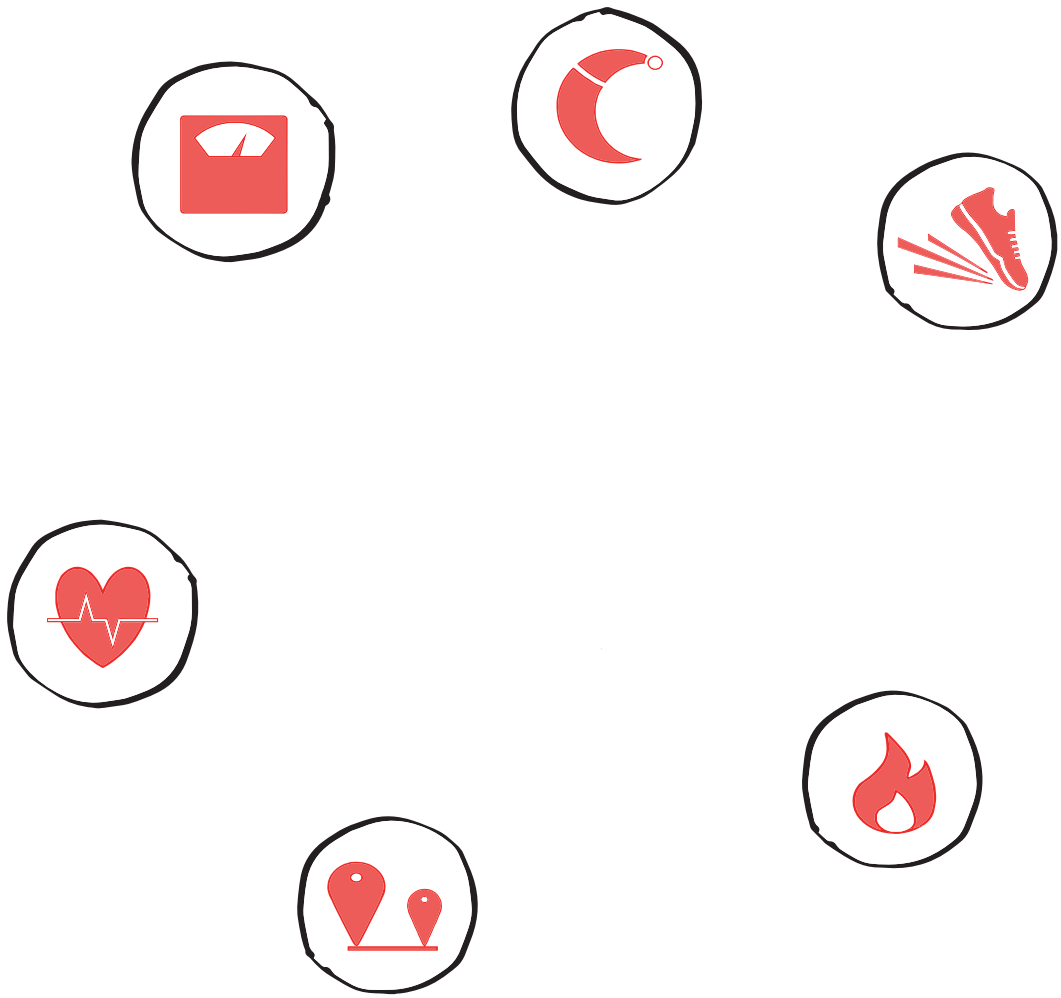
Chapter 1 |

General introduction



The current health care system has begun to change. Rising costs, an ageing population, and an increase in the number of people with lifestyle related diseases have exposed the need for a transformation from a centralized health care model towards one that is user-centered and preventive.[1,2] In the centralized model, health care is delivered from centralized places such as health care institutions and hospitals. Patients have a relatively inactive role in their disease management in this model. Evaluations and patient-related measurements are primarily conducted within the walls of the health care facility. In contrast, in the user-centered model, self-management is an important concept. Self-management is defined as the tasks that a person must do to monitor their own health and to make adjustments towards a satisfying health.[3] The patient is more informed, has more responsibility, and is even a producer of individual knowledge. This focus on self-management is also reflected in a renewed conceptualization of health: 'the ability to adapt and self-manage in the face of social, physical, and emotional challenges'.[4] There is a general consensus that shifting the focus from 'care' to 'self-management' is crucial for many patient groups to be able to achieve sufficient disease management and subsequently a satisfying quality of life.[1,2,5,6]

An important reason for the need of a renewed health care model is the large group of people with overweight/obesity and the related chronic diseases. This group has been growing rapidly over the last few decades, with now one in every two adults in Europe having overweight (BMI 25-30) and one out of six having obesity (BMI>30).[7–9] Overweight/obesity increases the risk of diabetes, cardiovascular diseases, cancer, and (neuro-)degenerative deterioration.[10] It is well known that lifestyle factors such as physical inactivity strongly contribute to the onset of overweight/obesity and type 2 diabetes[9,10] whereas engagement in sufficient physical activity such as 7500-10.000 steps per day is associated with major health benefits such as a healthy weight and glucose metabolism, a better functional performance, a lower risk for various chronic diseases, and a better quality of life.[11,12]

However, despite of the widespread evidence of the benefits of physical activity, most people do not comply with physical activity recommendations. In addition, attempts to increase physical activity within intervention programs, e.g., by education or counseling, are often disappointing. For instance, adherence to exercise recommendations of health care professionals has been found to be low in people with type 2 diabetes, but also in other patient groups.[13,14] This low adherence is caused by different reasons, e.g., lack of motivation, lack of an adequate exercise plan, and an inadequate building up which causes injuries.[14] Also, intrapersonal factors (perceived health and beliefs towards physical activity), social factors (lack of support from friends or family), organizational factors (lack of accessible exercise facilities and costs), and environmental factors (friendly physical activity environment) have been determined as being relevant barriers for people with mobility problems to engage in physical activity.[13] Barriers for exercise in a general middle aged and elderly population are partly overlapping: lack of time, tiredness, lack of knowledge how to be active, inconvenience of being active, lack of an exercise companion, interference with

work or social activities, and lack of exercise facilities.[15] Therefore, more knowledge is needed on how to overcome these barriers to physical activity and how to increase physical activity in the general population, individuals with overweight/obesity, and those with type 2 diabetes.

A possible, relatively new approach for stimulation of physical activity is the deployment of eHealth technology [1,16] which refers to the use of internet and communication technologies to improve health, well-being, and healthcare.[16] The manifestation of eHealth technology is very varied and can include digital health platforms, difference types of self-monitoring devices, smartphone applications, and patient monitoring systems. eHealth might have many benefits for health care delivery. For example, health data that is electronically uploaded by patients can add valuable information for the health care provider for both diagnosis and treatment purposes. In addition, the design and manifestation of eHealth technology can be adapted for a specific goal or target group, and eHealth can increase access to care (e.g., it is flexible with regard to time and place, or individuals who have a rare disease or live in rural areas might receive better access to care).[1,16,17] Digital self-monitoring devices are a form of eHealth. Self-monitoring devices are often wearable devices that enable the user to monitor, for example, physical activity, diet, sleep, respiration, heart rate, blood pressure, or blood glucose.[18] These self-monitoring devices are also known as 'self-tracking devices', 'health self-quantification devices', or simply 'wearables'. Self-tracking devices are increasingly acknowledged as possible facilitators for self-management abilities.[18–21] This is because of their ability to empower people with insight into their own health data and associated possibilities to stimulate the adoption of healthier behavior based on this data. For example, an individual who wants to increase his or her exercise activities is now able to gain insight into their current physical activity pattern through the use of an activity tracker. Whit this data visualized on an internet account or mobile application the user can see the course of their own physical activity pattern over time and how this is related to health recommendations such as taking a certain number of steps per day. This prevents overestimation of individual physical activity behavior and might stimulate making behavioral adjustments in physical activity habits, for example, by means of goals, reminders, prompts, and rewards.

From a theoretical perspective on behavioral change, self-monitoring of behavior is known as one of the self-regulation skills that are crucial to motivate and guide the desired behavior.[22] Another important self-regulation skill is goal-setting. Interventions targeting lifestyle behaviors have been shown to be more effective when these self-regulation components were included.[23,24] Therefore, goal-setting and self-monitoring of behavior are used as important Behavioral Change Techniques (BCTs).[25,26] Other important BCTs are providing information (tips and suggestions on how to increase physical activity), prompting review of behavior, providing feedback on behavior, and rewards. All of these BCTs are being increasingly incorporated within modern consumer activity trackers.[27] What is conceptually new about these devices is that they provide the user with objective knowledge about

individual daily routines and provide different forms of feedback which stimulates learning.[28] This may enhance sustained behavior change.[29,30]

Modern consumer level technology may thus have potential for broad applications for both general public health purposes and within health care for specific patient groups. However, before activity trackers can be deployed within health care, they must comply with certain conditions such as a satisfying reliability and validity. Not much is known yet about the reliability and validity of the large number of activity trackers that are currently on the market. This information is very important for users, health care providers, and researchers in order to be able to rely on information from these devices.

Another important point of consideration when using self-tracking technology, is knowledge about the adoption of these devices. Before self-tracking technology can impact behavior, they must be adopted by the user, and there has to be an certain engagement with the device.[31] Although the development of self-monitoring technology has led to an increased number of people who actively engage in self-measurements,[18] the sustained use of wearable devices by consumers is not yet that high. Several studies on the adoption of consumer level self-tracking devices have found that the percentages of people who stopped using their device within relative short-term follow up periods may vary between 33 and 75%.[32–35] Factors that influence the adoption of self-monitoring technology are not yet completely clear. Factors determined thus far include different types, including personal factors, devices factors, and behavioral factors.[32–34,36] Not much is known yet about theory based behavioral factors that explain adoption of technology. Knowledge about these factors is important in order to be able to tailor interventions based on this information, direct future developments, or possibly distinguish between people who may or may not be suitable for treatment with use of modern consumer level technology.

When activity trackers are employed as (part of) an intervention to increase physical activity, an important condition is knowledge about the potential effects this technology may have. At the moment, eHealth including consumer activity trackers is not yet widely used in healthcare.[16,37,38] In accordance with this, not much is known yet about the impact of these devices on lifestyle behaviors and health outcomes both in the general population as well as for people who have overweight/obesity, or type 2 diabetes. As described earlier, the use of consumer-level self-monitoring devices that can measure physical activity might be an effective approach for the incremental increase of physical activity, including people with overweight/obesity or individuals who have type 2 diabetes. However, thus far, mostly simple pedometers without additional BCTs have been deployed in interventions targeting this group, and the evidence for physical activity and health outcome measures such as weight/BMI and glycemic control is not yet conclusive.[39,40] Therefore, more knowledge is needed about the effectiveness of eHealth technology, including the use of activity trackers.

Aims and outline of this dissertation

This dissertation aims to increase knowledge about the use and effectiveness of eHealth and self-monitoring techniques, especially activity trackers, in the current healthcare system. The focus will be on the general population as well on people with overweight/obesity and those with type 2 diabetes. Three domains will be distinguished.

The *first domain* is the reliability and validity of new consumer self-tracking devices. Before new technology can be integrated into health care, it must be known whether these devices are reliable and valid. Therefore, the purpose of **Chapter 2 and 3** is to examine the reliability and validity of 20 activity trackers, apps, and smartwatches.

The *second domain* focuses on the adoption of self-monitoring devices in the general population. For this, the purpose in **Chapter 4** is to examine the adoption and factors associated with the adoption of self-tracking devices that quantify physical activity, sleep, and weight.

The *third domain* is about the effect of using consumer level activity-tracking devices and eHealth applications in healthy people, people with overweight/obesity, and those with type 2 diabetes. First, the aim of **Chapter 5** is to systematically review all studies done so far to the impact of self-monitoring of physical activity on activity levels in people with overweight and obesity. In **Chapter 6** a randomized controlled trial will be conducted to the effect of a modern consumer activity tracker connected to an online lifestyle program on physical activity, glycemic control, and other health outcome measures in people with type 2 diabetes. The purpose of **Chapter 7** is to investigate short-term and long-term effects of self-tracking of physical activity and weight on BMI change in the general population and to what extent a change in self-regulation capabilities can explain weight loss.

References

1. Arnrich B, Mayora O, Bardram J, Trster G. Pervasive healthcare. *Methods Inf Med*. 2010;49(1):67-73.
2. Swan M. Emerging patient-driven health care models: an examination of health social networks, consumer personalized medicine and quantified self-tracking. *Int J Environ Res Public Health*. 2009;6(2):492-525.
3. El-Gayar O, Timsina P, Nawar N, Eid W. A systematic review of IT for diabetes self-management: Are we there yet? *Int J Med Inform*. 2013;82(8):637-652. doi:10.1016/j.ijmedinf.2013.05.006.
4. Huber M, André Knottnerus J, Green L, et al. How should we define health? *BMJ*. 2011;343(7817). doi:10.1136/bmj.d4163.
5. Sharon T. Self-Tracking for Health and the Quantified Self: Re-Articulating Autonomy, Solidarity, and Authenticity in an Age of Personalized Healthcare. *Philos Technol*. 2016:1-29.
6. Panagioti M, Richardson G, Small N, et al. Self-management support interventions to reduce health care utilisation without compromising outcomes: a systematic review and meta-analysis. *BMC Health Serv Res*. 2014;14(1):356. doi:10.1186/1472-6963-14-356.
7. Tamayo T, Rosenbauer J, Wild SH, et al. Diabetes in Europe: An update. *Diabetes Res Clin Pract*. 2014;103(2):206-217. doi:10.1016/j.diabres.2013.11.007.
8. Eurostat. European Health Interview Survey: Almost 1 adult in 6 in the EU is considered obese. *Prem Off News*. 2016;2014(October):7-11. http://ec.europa.eu/eurostat/documents/2995521/7700898/3-20102016-BP-EN.pdf/c26b037b-d5f3-4c05-89c1-00bf0b98d646.
9. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet*. 2012;380(9838):219-229. doi:10.1016/S0140-6736(12)61031-9.
10. Musto AA. The effects of an incremental pedometer program on metabolic syndrome components in sedentary overweight women. *Diss Abstr Int Sect B Sci Eng*. 2008;69(3-B):1598. http://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,shib&db=psyh&AN=2008-99180-343&site=ehost-live&custid=s4121186.
11. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;39(8):1423-1434. doi:10.1249/mss.0b013e3180616b27.
12. Tudor-Locke C, Craig CL, Brown WJ, et al. How many steps/day are enough? for adults. *Int J Behav Nutr Phys Act*. 2011;8(1):79. doi:10.1186/1479-5868-8-79.
13. Vasudevan V, Rimmer JH, Kviz F. Development of the Barriers to Physical Activity Questionnaire for People with Mobility Impairments. *Disabil Health J*. 2015;8(4):547-556. doi:10.1016/j.dhjo.2015.04.007.
14. García-Pérez, L. E., Álvarez, M., Dilla, T., Gil-Guillén, V., & Orozco-Beltrán D. Adherence to Therapies in Patients with Type 2 Diabetes. *Diabetes Ther*. 2013;4(2):175-194. doi:10.1007/s13300-013-0034-y.
15. Justine M, Azian A, Hassan V, Manaf H. Barriers to participation in physical activity and exercise among middle-aged and elderly individuals. *Singapore Med J*. 2013;54(10):581-586.
16. Van Gemert-Pijnen, J.E.W.C, Peters,O., & Ossebaard HC. *Improving eHealth*. Eleven International Publishing; 2013. http://lib.myilibrary.com?ID=673579.
17. Steinhubl SR, Muse ED, Topol EJ. Can Mobile Health Technologies Transform Health Care? *Jama*. 2013;310(22):2395. doi:10.1001/jama.2013.281078.
18. Fawcett T. Mining the Quantified Self: Personal Knowledge Discovery as a Challenge for Data Science. *Big Data*. 2015;3(4):249-266. internal-pdf://228.60.152.96/Fawcett.
19. Almalki M, Gray K, Martin-Sanchez F. Activity Theory as a Theoretical Framework for Health Self-Quantification: A Systematic Review of Empirical Studies. *J Med Internet Res*. 2016;18(5):e131.
20. Grnvall E, Verdezoto N. Beyond self-monitoring: understanding non-functional aspects of home-based healthcare technology. In: *Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM; 2013:587-596.
21. Almalki M, Gray K, Martin-Sanchez F. Refining the Concepts of Self-quantification Needed for Health Self-management: A Thematic Literature Review. *Computer (Long Beach Calif)*. 2015;79:1-5.
22. Bandura A. Health promotion from the perspective of social cognitive theory. *Psychol Heal*. 1998;13(4):623-649.
23. Greaves CJ, Sheppard KE, Abraham C, et al. Systematic review of reviews of intervention components

associated with increased effectiveness in dietary and physical activity interventions. *BMC Public Health*. 2011;11(1):1.
24. Teixeira PJ, Carraa E V, Marques MM, et al. Successful behavior change in obesity interventions in adults: a systematic review of self-regulation mediators. *BMC Med*. 2015;13(1):1.
25. Michie S, Ashford S, Sniehotta FF, Dombrowski SU, Bishop A, French DP. A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: The CALO-RE taxonomy. *Psychol Health*. 2011;26(11):1479-1498. doi:10.1080/08870446.2010.540664.
26. Michie S, Richardson M, Johnston M, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann Behav Med*. 2013;46(1):81-95.
27. Lyons EJ, Lewis ZH, Mayrsohn BG, Rowland JL. Behavior change techniques implemented in electronic lifestyle activity monitors: A systematic content analysis. *J Med Internet Res*. 2014;16(8). doi:10.2196/jmir.3469.
28. Menninga K. Learning abstinence theory - PhD thesis under supervision of A. Dijkstra. *Univ Groningen*. 2012.
29. Carver CS, Scheier MF. Control theory: A useful conceptual framework for personality-social, clinical, and health psychology. *Psychol Bull*. 1982;92(1):111-135. doi:10.1037/0033-2909.92.1.111.
30. Kluger AN, DeNisi A. The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychol Bull*. 1996;119(2):254-284. doi:10.1037/0033-2909.119.2.254.
31. Perski O, Blandford A, West R, Michie S. Conceptualising engagement with digital behaviour change interventions: a systematic review using principles from critical interpretive synthesis. *Transl Behav Med*. 2016:1-14.
32. Fritz T, Huang EM, Murphy GC, Zimmermann T. Persuasive technology in the real world: a study of long-term use of activity sensing devices for fitness. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM; 2014:487-496.
33. Gouveia R, Karapanos E, Hassenzahl M. How do we engage with activity trackers?: a longitudinal study of Habito. In: *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM; 2015:1305-1316.
34. Lazar A, Koehler C, Tanenbaum J, Nguyen DH. Why we use and abandon smart devices. In: *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM; 2015:635-646.
35. Clawson J, Pater JA, Miller AD, Mynatt ED, Mamykina L. No longer wearing: investigating the abandonment of personal health-tracking technologies on craigslist. In: *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM; 2015:647-658.
36. Epstein D, Caraway M, Johnston C, Ping A, Fogarty J, Munson S. Beyond Abandonment to Next Steps. In: CHI '16. ACM; :1109-1113. doi:10.1145/2858036.2858045.
37. Griebel L, Kolominsky-Rabas P, Schaller S, et al. Acceptance by laypersons and medical professionals of the personalized eHealth platform, eHealthMonitor. *Informatics Heal Soc Care*. 2016:1-18.
38. Paton C, Hansen M, Fernandez-Luque L, Lau a YS. Self-Tracking, Social Media and Personal Health Records for Patient Empowered Self-Care. Contribution of the IMIA Social Media Working Group. *Yearb Med Inform*. 2012;7(1):16-24. doi:me12010016 [pii].
39. Rollo M, Aguiar E, Williams R. eHealth technologies to support nutrition and physical activity behaviors in diabetes self-management. *Obes Targets …*. 2016;9:381. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5104301/.
40. McMillan KA, Kirk A, Hewitt A, MacRury S. A systematic and integrated review of mobile-based technology to promote active lifestyles in people with type 2 diabetes. *J Diabetes Sci Technol*. 2017;11(2):299-307.